EMCAL (WBS 1.4)

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Overview WBS 1.4

- Introduction and overview of the BTeV Electromagnetic Calorimeter (WBS 1.4 – EMCAL)
- Detector overview
- Project management overview
- EMCAL R&D (used for cost and schedule estimates)
- Summary & Presentations prepared for the breakout sessions

Introduction WBS 1.4

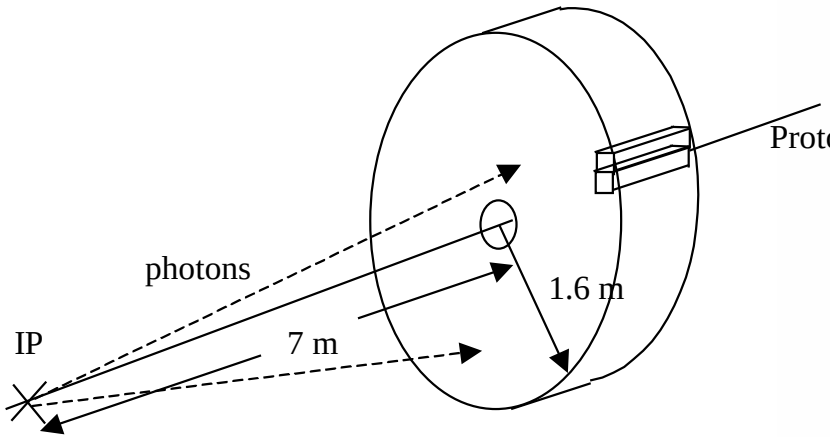
- The role of BTeV EMCAL is to reconstruct photons and help identify electrons with high resolution and efficiency in a high-rate (and high radiation) environment.
- Energy and position resolution goals (better than requirements) are

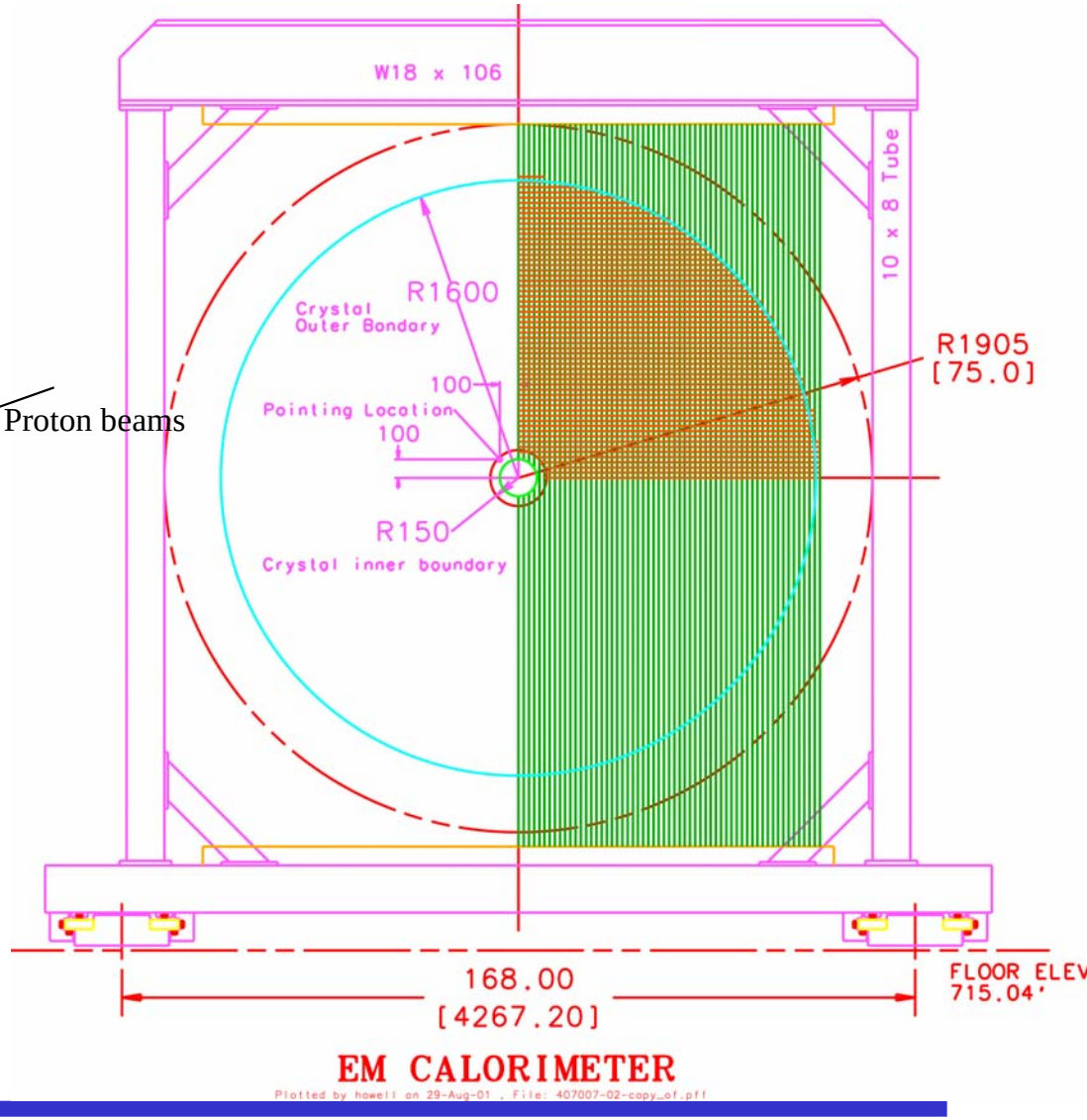
$$\frac{\sigma_E}{E} = \left(0.55 \oplus 1.8/\sqrt{E}\right)\ \% \text{ and}$$

$$\sigma_x = \left(0.2 \oplus 3/\sqrt{E}\right) \text{mm, where } E \text{ is in GeV.}$$

- Lead-Tungstate ($PbWO_4$ or PWO) scintillation crystals are used to detect photons.
- Photomultiplier tubes (PMT) are used to detect scintillation light (no *B* field)
- Custom ASIC – QIE – is used to digitize signal with 0.6% step size in 8 ranges and pseudo log-scale ADC (FNAL has much experience with QIE – KTeV, CDF, CMS, MINOS)

3 D view and Front view WBS 1.4



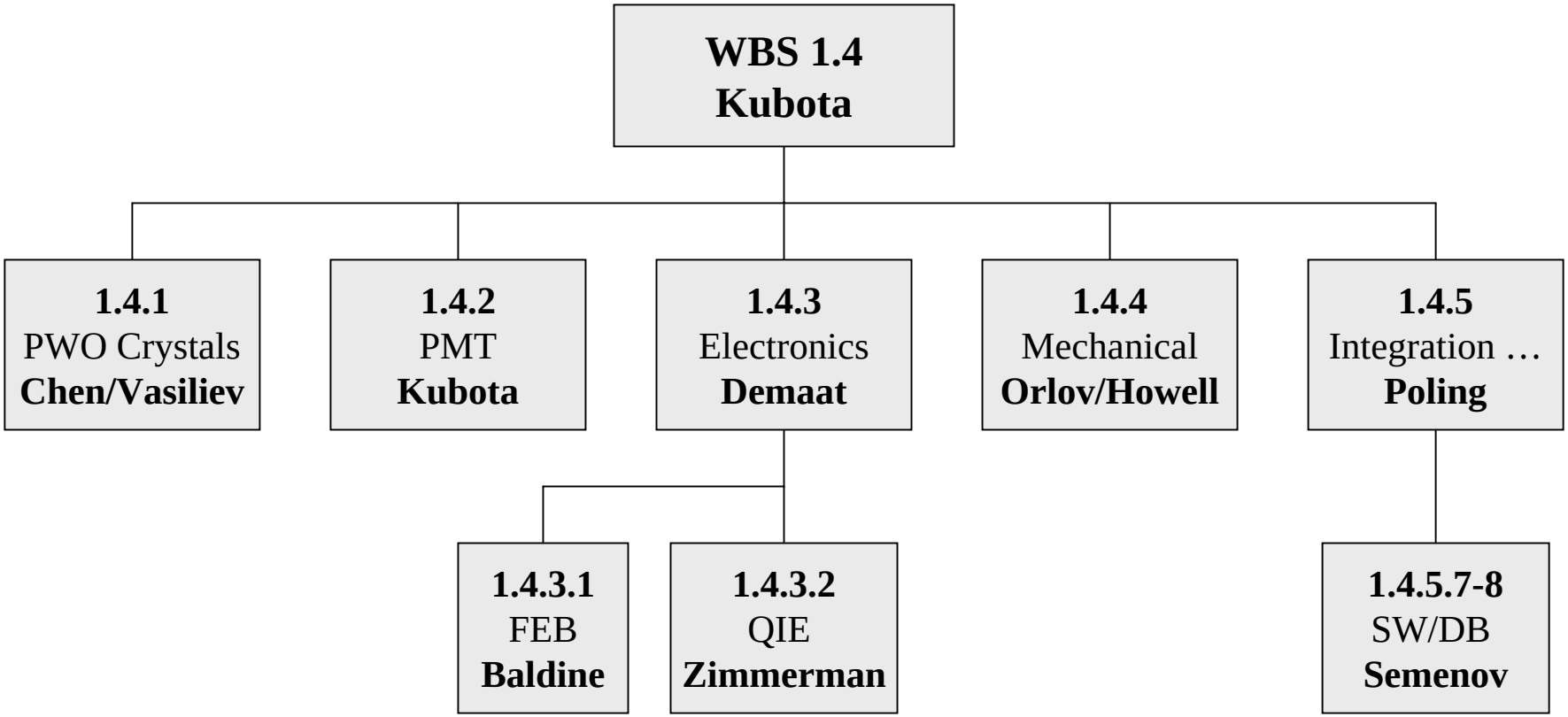


Lead Tungstate Crystals WBS 1.4

- Why Lead Tungstate Crystals
  - Excellent energy and spatial resolution.
  - Fast – no tail in the next crossing
  - Compact – minimum shower overlap
  - Rad hard – survive hadron machine environment

Organization WBS 1.4

Base cost: $12.3M (Material: $10.1M, Labor: $2.2M)



R&D results

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- Resolution
- Radiation hardness of PWO (and other components)
- Calibration scheme
- Light calibration system – 0.1%
- Mechanical structure
- MC –
  - electron rates for calibration;
  - radiation levels
  - Feasibility of muon calibration
  - Effect of 1% resolution
- Source based measurements of radiation tolerance of crystal for QA

- QIE: design is progressing & expect the prototype submission this year
- Develop FEB to utilize QIE prototype @FNAL testbeam
- Radiation hardness of optical glue – 10 qualify
- Radiation hardness of wrapping materials – Tyvek, Teflon and aluminized Myler all work

Mechanical Design and Prototype WBS 1.4

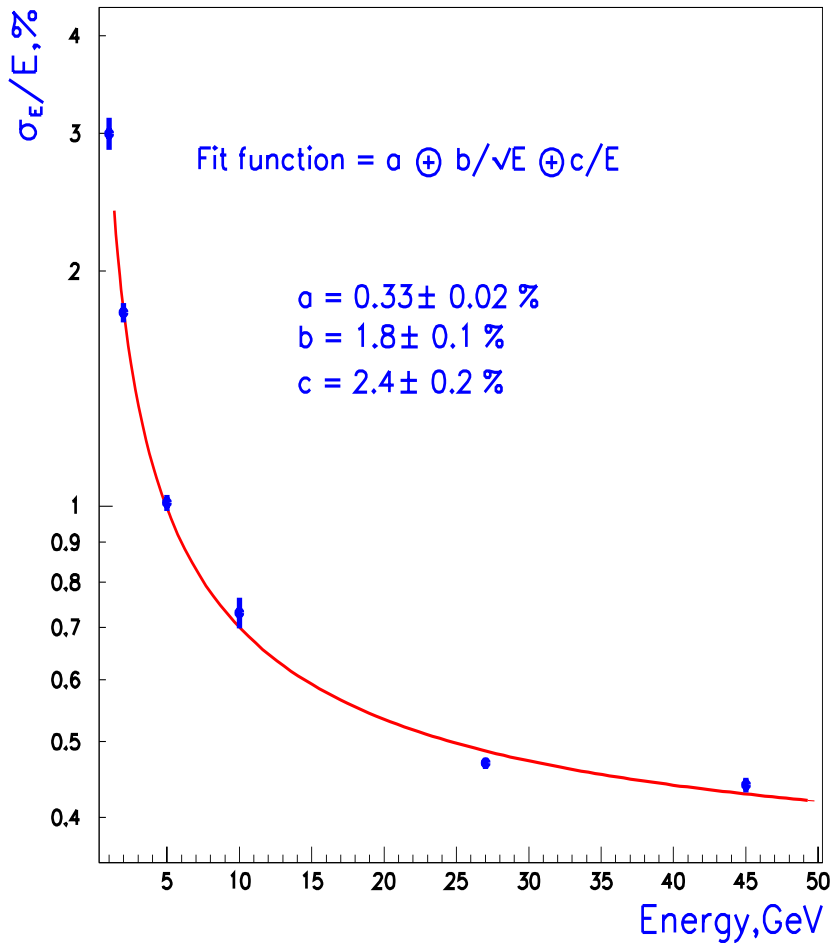
- Gave up CMS-endcap design (carbon fiber cells) – expensive, not needed.

Successful

Good for cost & estimates

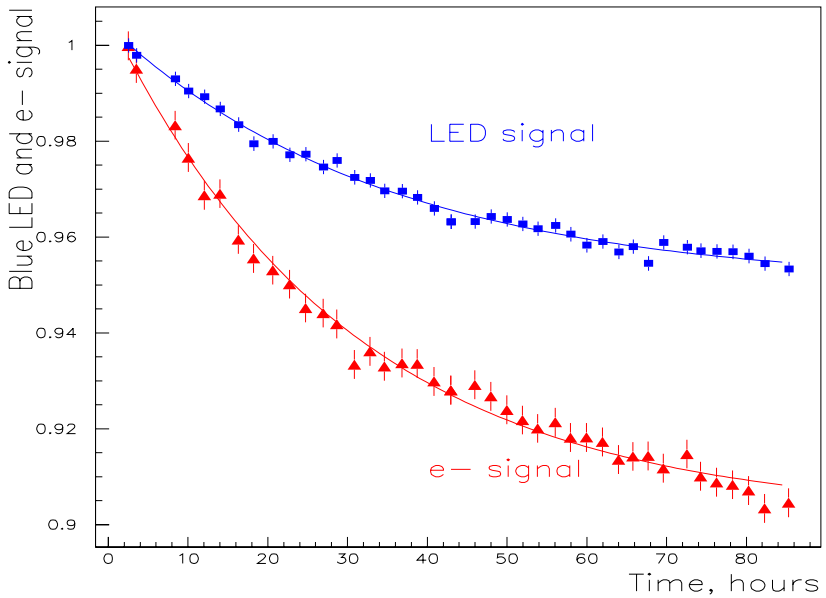
Test beam Results: Energy Resolution

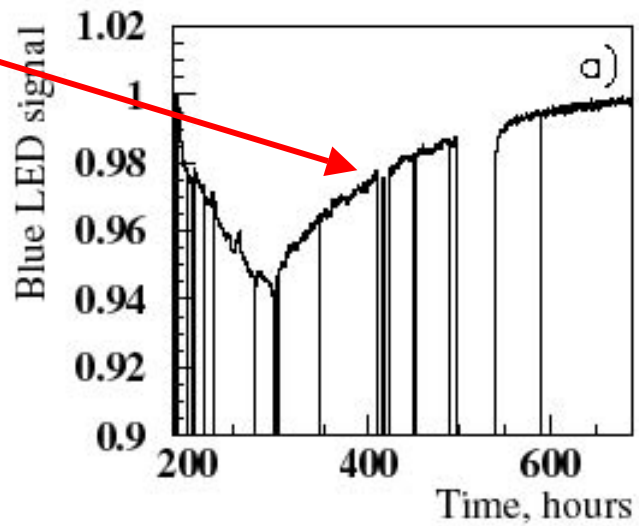
- Agreement with our Monte Carlo prediction
  - constant term (a) (uniformity and shower leakage), and
  - stochastic term (b) (shower leakage and photon stat. [~ 5 p.e./MeV])
  - "noise" term (c) is actually due to momentum measurement error of electron beam due to multiple scattering



Light loss from Radiation WBS 1.4

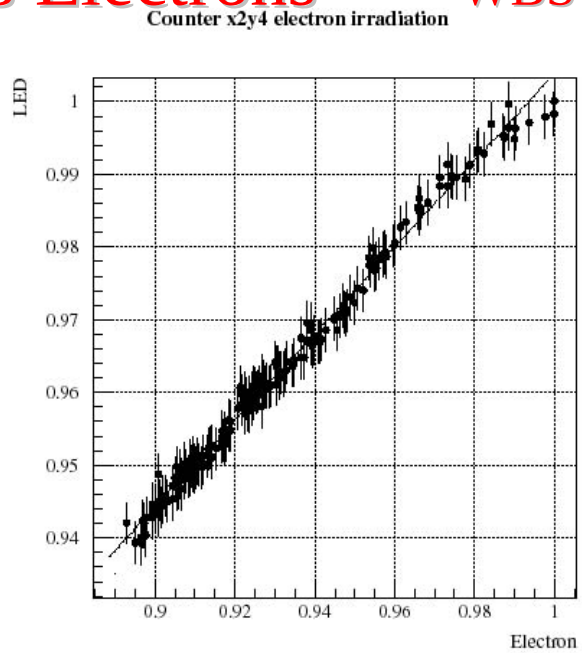
- Light loss (at dose rate of 15 rad/h) is exponential and saturates.
- Confirmation of damage recovery mechanism
- Time constant of loss is ~30 hours.

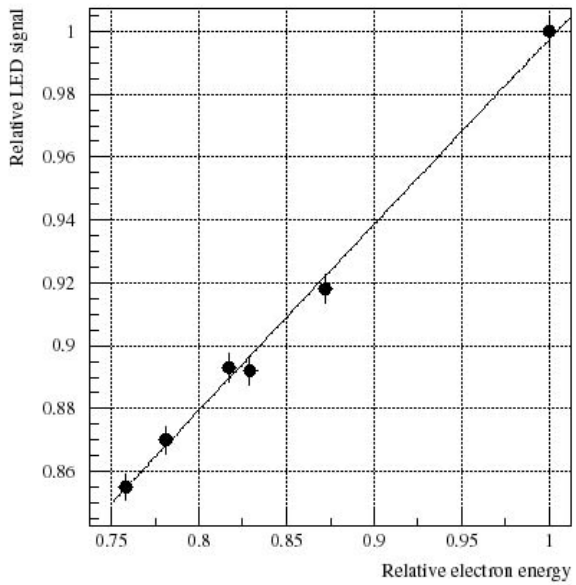




Correlation: LED *vs* Electrons

- The ratio of their changes (or slope of the graphs) is important to know.
- Then we can correct the particle data using LED data.

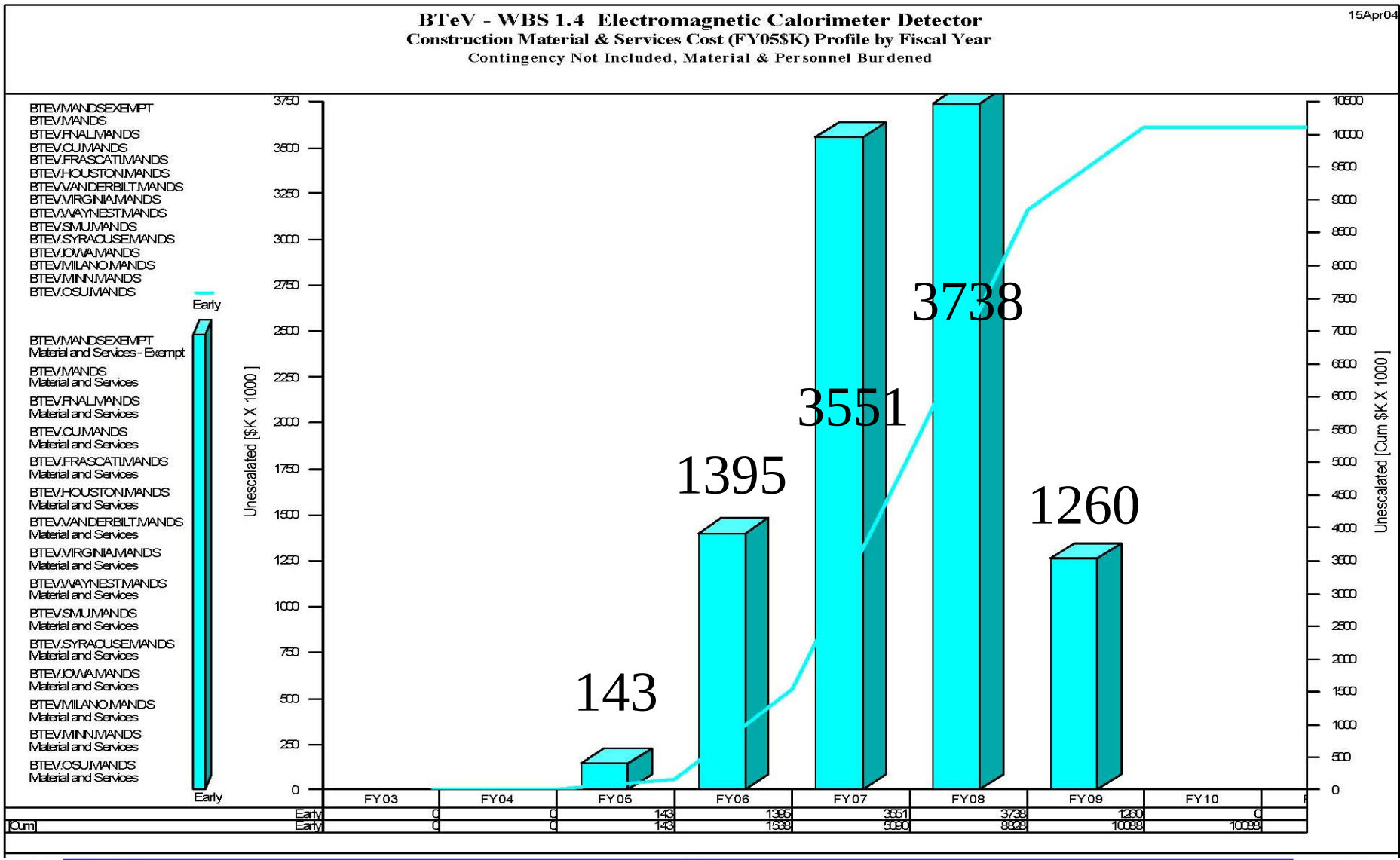




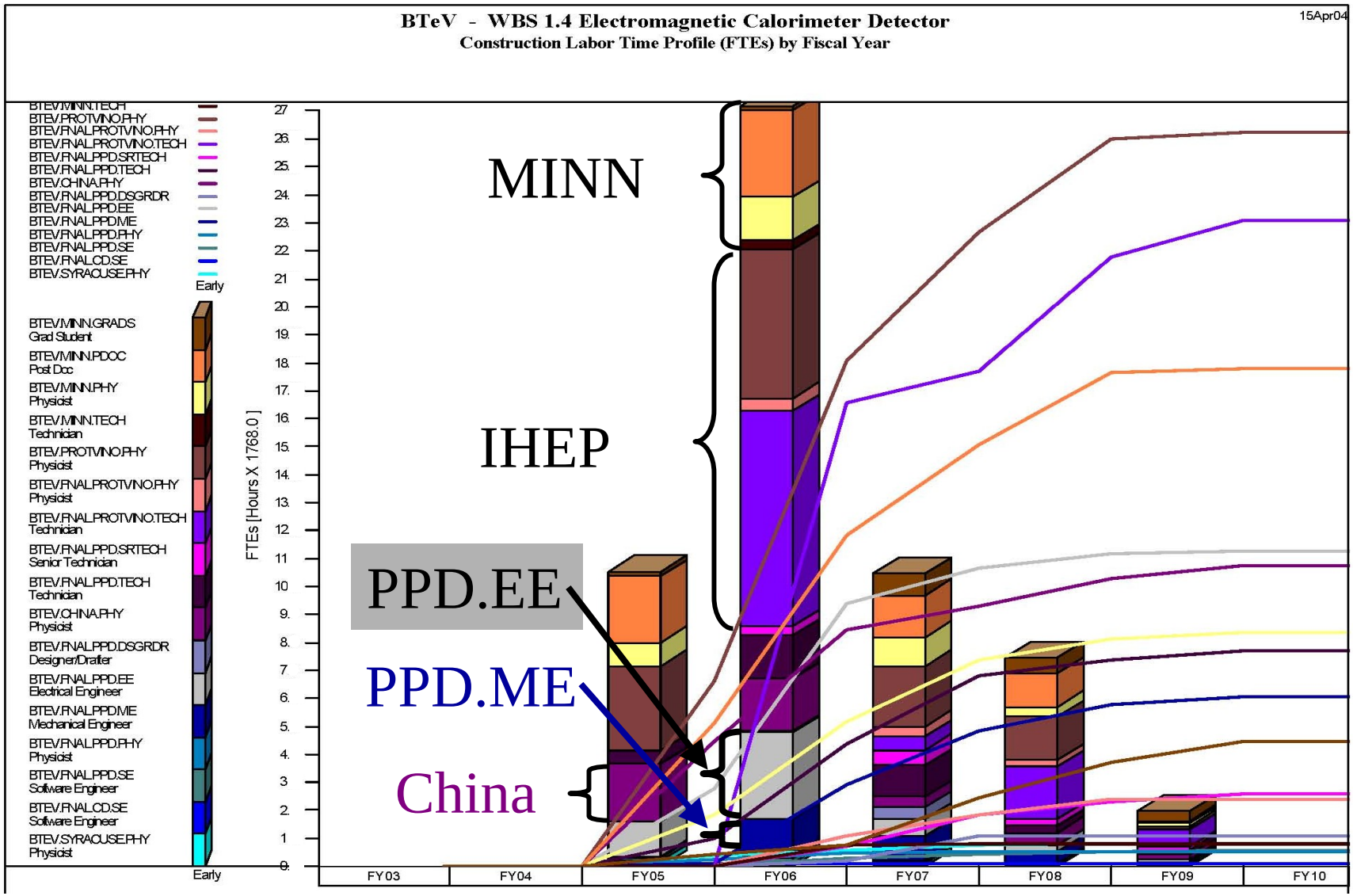
Construction Cost WBS 1.4

Activity ID	Activity Name	Base Cost ($)	Material Contingency (%)	Labor Contingency (%)	Total FY05	Total FY06	Total FY07	Total FY08	Total FY09	Total FY05-09
1.4.1	Detector - PWO Crystals	5,848,018	40	30	55,146	958,809	1,576,859	3,816,967	1,751,893	8,159,675
1.4.2	Detectors - PMT's bases	2,277,301	28	22	2,525	203,353	1,357,920	1,315,530	21,864	2,901,191
1.4.3	EMCAL Electronics and Associated Infrastructure	2,135,006	30	30	387,907	469,960	1,907,328	10,111	0	2,775,305
1.4.4	Mech Air and Temperature ctrl Systems	1,003,013	20	24	0	654,561	368,532	150,369	52,925	1,226,388
1.4.5	Integration and Testing	733,407	26	26	4,376	909,830	0	7,650	0	921,856
1.4.6	EM Calorimeter Detector Subproject Management	258,999	38	25	43,353	77,248	73,697	107,282	30,471	332,052
1.4	**Subproject 1.4**	**12,255,743**	**35**	**26**	**493,307**	**3,273,761**	**5,284,336**	**5,407,909**	**1,857,153**	**16,316,466**

M&S Obligation Profile by Fiscal YearWBS 1.4

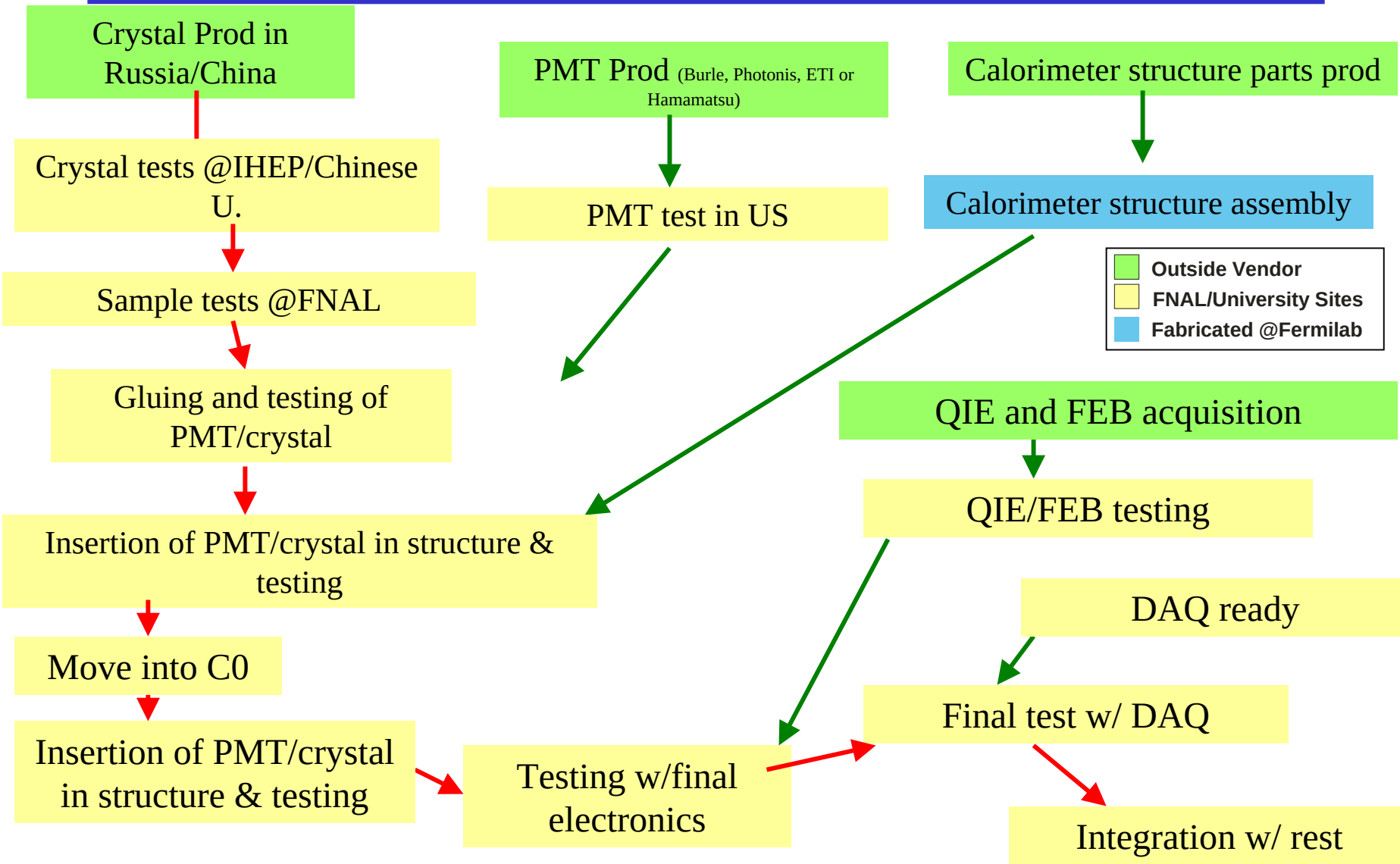


Labor Profile by Fiscal Year WBS 1.4



Project Flow

WBS 1.4



Key Milestones WBS 1.4

QIE Production Order Submitted	November-04
PWO Crystal Purchase OrderPlaced	November-05
PMT's Vendor approved	January-06
1st Shipment PMT's Accepted.	April-07
1st Shipment PWO crystals Accepted (all vendors)	August-07
Calorimeter Structure Ready for C0	December-07
Initial Gluing of PMTs & Crystal Complete	January-08
ADC card checkout Complete	February-08
PMT's Procured.	September-08
PWO crystals Procured	July-09
Gluing of PMTs & Crystal Complete	August-09
Assembly of EMCAL Complete	August-09

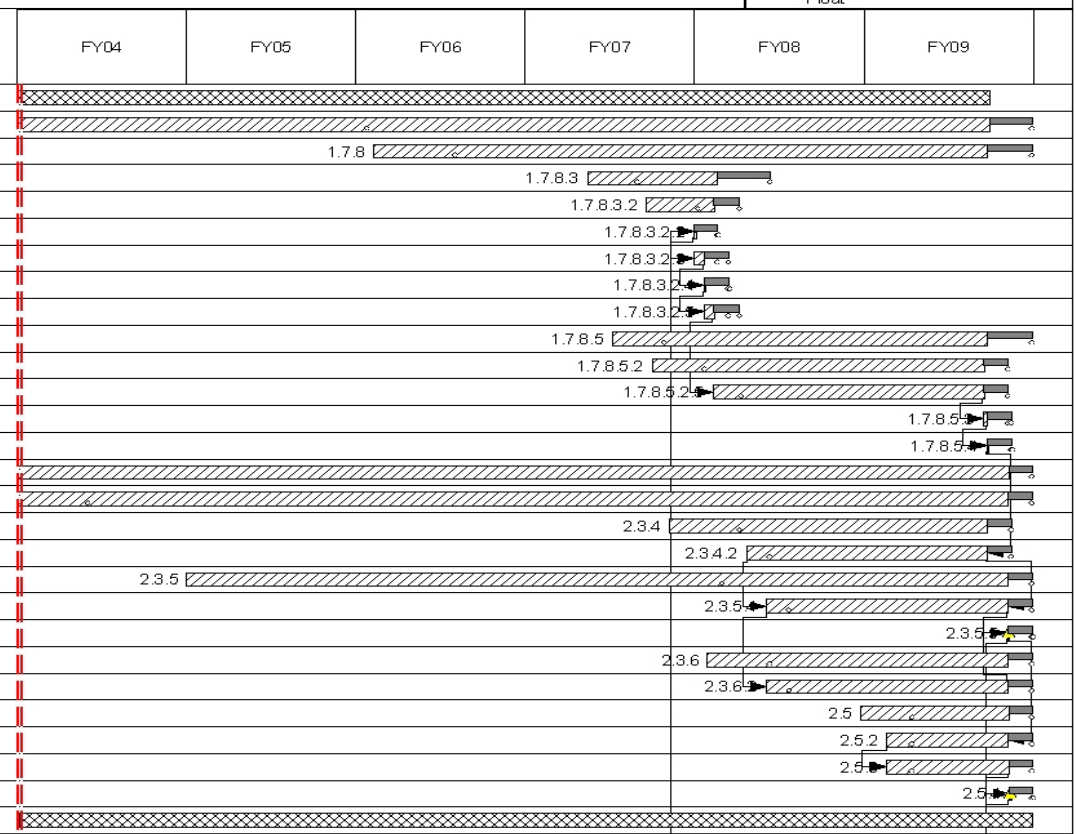
Critical Path Activities WBS 1.4

BTeV - WBS 1.4 Electromagnetic Calorimeter Detector
Total Construction Cost Profile ($K) by Institution & Fiscal Year
Fermilab Labor: Salary, OPTO, Vacation, Fringe & Overhead
Non-Fermilab Labor: Salary, Benefits & Overhead
No Contingency, No Escalation, No Full material Procurement 'Burdening'

16Apr04

Planned
Critical
Late Dates
Milestone
Progress
Summary
Float

Activity ID	Activity Description
1	Detector - PWO Crystals
1.7	Procurement of EM Calorimeter PWO crystals
1.7.8	Prod PWO MAnufac and Del
1.7.8.3	Manufac & Del of Prod PWO vendor A 2nd shpmnt
1.7.8.3.2	Vendor A 2nd Shipment - MINN
1.7.8.3.2.1	Vendor A 2nd Shipment of PWO crystals to US
1.7.8.3.2.3	clear customs for Vendor A 2nd Shipment of PWO
1.7.8.3.2.4	Lev3Mil: Received 2nd batch of Crystals (A)
1.7.8.3.2.5	Sample Perf Accept Test of 2nd Shipment of PWO
1.7.8.5	Manufac & Del of Prod PWO vendor A final shpmnt
1.7.8.5.2	Vendor A 2nd Shipment - MINN
1.7.8.5.2.5	Sample Perf Accept Test of Final Shipment of PWO
1.7.8.5.3	Lev2Rvw: Final Shipment PWO Accepted (A)
1.7.8.5.4	Lev3Mil: Final Shipment PWO crystals Accepted
2	Detectors - PMT's, bases
2.3	Attach crystals to PMT's
2.3.4	Glue of PMT's to crystals - MINN
2.3.4.2	Gluing the remaining crystals & PMT's (US)
2.3.5	Test crystal-PMT assemblies
2.3.5.4	Glue PMT/PWO - remaining batch
2.3.5.5	Lev2Mil: Gluing of PMTs & Crystal Complete
2.3.6	Test crystal-PMT assemblies - IHEP/FNAL
2.3.6.2	Test Glue Joints of Remaining PWO-PMT Assemblies
2.5	Crystal Insertion in C0 - move to 1.10
2.5.2	Insert PMT/crystal,
2.5.3	Test Installed Elements
2.5.4	Lev1Mil: Assy of ECal Compl
7	BTeV Project Lev1Mils



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Critical Path Analysis (1) WBS 1.4

- The smallest float is for Russian crystal production to their utilization (35 days). This is because we have to delay their production until funding is available in FY07.
- The next smallest float is for Chinese crystal production (38 days). Even though we plan to start crystal production in FY06, it has to be stretched due to its production capacity and funding availability. If more funding is available in FY08, this will speed up the crystal acquisition without leaving too many to produce in FY09 and float will be increased.
- Insertion of crystal-PMT assemblies (in Assembly Hall) has 74 days of float. Even though we assume that half of the assemblies will be inserted in the Assembly Hall, and the remaining will be in the C0 Hall, if there is a delay, more will be inserted in the C0 Hall.

Critical Path Analysis (2) WBS 1.4

- PMT base production has 74 days of float. This again is because we will not have sufficient funding for this activity until FY07. If we can obtain $250k in FY06, the float can be increased substantially.
- Building of crystal testing set ups has a float of 144 days. This is mostly because the lack of funding in FY05, and cannot be started until FY06. FY05 funding for EMCAL is mostly used to fabricate QIE chips, which is urgent to make sure that we obtain them before their production technology becomes obsolete.

Risk Analysis

Risk Event	Response/mitigation strategy
Cost of PWO crystals	• Keep three vendors (Shanghai, Bogoroditsk and Northern Crystals) viable • Keep up with their plans
Delay in PWO crystal production	• Same as above. • Partial installation of PMT/crystals is a viable option – the remaining crystals can be installed during relatively short access time.
Delay in PMT production	• w/ 4 potential vendors, some trade off between cost and schedule is possible. • Partial installation of PMT/crystals is a viable option.
Delay in the QIE production	• We are submitting prototype chips this year, and will move to production ASAP.

Summary for WBS 1.4

- No significant technical issues remain.
- Cost & schedule have been established bottoms-up using OpenPlan.
- Base $12.3M and 33% contingency for $16.3M total
- Minimum float of 35 days is very short – partial solution includes forward funding from universities, and commission with partial crystal installation.

More information for WBS 1.4 is available in the breakout sessions.

- Responses to Temple 03 – Yuichi Kubota
- Effects of radiation on PWO and Calibration issues – Yuichi Kubota
- Scintillation mechanism damage *vs.* transmission damage of PWO – Alexander Vasiliev
- Crystal quality assurance – Alexander Vasiliev
- Electron rate studies for physics calibration – Julia Yarba